Chapter 1
Surgical Anatomy, Embryology, and Physiology of the Salivary Glands

John D. Langdon, FKC, MB BS, BDS, MDS, FDSRCS, FRCS, FMedSci
King’s College, London, UK

Outline
Introduction
The Parotid Gland
Embryology
Anatomy
Contents of the Parotid Gland
The Facial Nerve
Auriculotemporal Nerve
Retromandibular Vein
External Carotid Artery
Parotid Lymph Nodes
Parotid Duct
Nerve Supply to the Parotid
The Submandibular Gland
Embryology
Anatomy
The Superficial Lobe
The Deep Lobe
The Submandibular Duct
Blood Supply and Lymphatic Drainage
Nerve Supply to the Submandibular Gland
Parasympathetic Innervation
Sympathetic Innervation
Sensory Innervation
The Sublingual Gland
Embryology
Anatomy
Sublingual Ducts
Blood Supply, Innervation, and Lymphatic Drainage
Minor Salivary Glands
Histology of the Salivary Glands
Control of Salivation

Summary
References

Introduction

There are three pairs of major salivary glands consisting of the parotid, submandibular, and sublingual glands. In addition, there are numerous minor glands distributed throughout the oral cavity within the mucosa and submucosa.

On average, about 0.5 liters of saliva are produced each day but the rate varies throughout the day. At rest, about 0.3 ml/min are produced but this rises to 2.0 ml/min with stimulation. The contribution from each gland also varies. At rest, the parotid produces 20%, the submandibular gland 65%, and the sublingual and minor glands 15%. On stimulation, the parotid secretion rises to 50%. The nature of the secretion also varies from gland to gland. Parotid secretions are almost exclusively serous, the submandibular secretions are mixed and the sublingual and minor gland secretions are predominantly mucinous.

Saliva is essential for mucosal lubrication, speech, and swallowing. It also performs an essential buffering role that influences demineralization of teeth as part of the carious process. When there is a marked deficiency in saliva production, xerostomia, rampant caries, and destructive periodontal disease ensues. Various digestive enzymes – salivary amylase – and antimicrobial
agents – IgA, lysozyme, and lactoferrin – are also secreted with the saliva.

**The Parotid Gland**

**EMBRYOLOGY**

The parotid gland develops as a thickening of the epithelium in the cheek of the oral cavity in the 15 mm Crown Rump length embryo. This thickening extends backwards towards the ear in a plane superficial to the developing facial nerve. The deep aspect of the developing parotid gland produces bud like projections between the branches of the facial nerve in the third month of intra-uterine life. These projections then merge to form the deep lobe of the parotid gland. By the sixth month of intra-uterine life the gland is completely canalized. Although not embryologically a bilobed structure, the parotid comes to form a larger (80%) superficial lobe and a smaller (20%) deep lobe joined by an isthmus between the two major divisions of the facial nerve. The branches of the nerve lie between these lobes invested in loose connective tissue. This observation is vital in the understanding of the anatomy of the facial nerve and surgery in this region (Berkovitz, et al. 2003).

**ANATOMY**

The parotid is the largest of the major salivary glands. It is a compound, tubuloacinar, merocrine, exocrine gland. In the adult, the gland is composed entirely of serous acini.

The gland is situated in the space between the posterior border of the mandibular ramus and the mastoid process of the temporal bone. The external acoustic meatus and the glenoid fossa lie above together with the zygomatic process of the temporal bone (Figure 1.1). On its deep (medial) aspect lies the styloid process of the temporal bone. Inferiorly, the parotid frequently overlaps the angle of the mandible and its deep surface overlies the transverse process of the atlas vertebra.

The shape of the parotid gland is variable. Often it is triangular with the apex directed inferiorly. However, on occasion it is more or less of even width and occasionally it is triangular with the apex superiorly. On average, the gland is 6 cm in length with a maximum of 3.3 cm in width. In 20% of subjects a smaller accessory lobe arises from the upper border of the parotid duct approximately 6 mm in front of the main gland. This accessory lobe overlies the zygomatic arch.

The gland is surrounded by a fibrous capsule previously thought to be formed from the investing layer of deep cervical fascia. This fascia passes up from the neck and was thought to split to enclose the gland. The deep layer is attached to the mandible and the temporal bone at the tympanic plate and styloid and mastoid processes (McMinn, et al. 1984; Berkovitz and Moxham 1988; Williams 1995; Ellis 1997). Recent investigations suggest that the superficial layer of the parotid capsule is not formed in this way, but is part of the superficial musculo-aponeurotic system (SMAS) (Mitz and

Peyronie 1976; Jost and Levet 1983; Wassef 1987; Thaller, et al. 1989; Zigiotti, et al. 1991; Gosain, et al. 1993; Flatau and Mills 1995). Anteriorly, the superficial layer of the parotid capsule is thick and fibrous but more posteriorly, it becomes a thin translucent membrane. Within this fascia are scant muscle fibers running parallel with those of the platysma. This superficial layer of the parotid capsule appears to be continuous with the fascia overlying the platysma muscle. Anteriorly, it forms a separate layer overlying the masseteric fascia, which is itself an extension of the deep cervical fascia. The peripheral branches of the facial nerve and the parotid duct lie within a loose cellular layer between these two sheets of fascia. This observation is important in parotid surgery. When operating on the parotid gland, the skin flap can either be raised in the subcutaneous fat layer or deep to the SMAS layer. The SMAS layer itself can be mobilized as a separate flap and can be used to mask the cosmetic defect following parotidectomy by reattaching it firmly to the anterior border of the sternocleidomastoid muscle as an advancement flap (Meningaud, et al. 2006).

The superior border of the parotid gland (usually the base of the triangle) is closely molded...
around the external acoustic meatus and the temporomandibular joint. An avascular plane exists between the gland capsule and the cartilaginous and bony acoustic meatus (Figure 1.2). The inferior border (usually the apex) is at the angle of the mandible and often extends beyond this to overlap the digastric triangle where it may lie very close to the posterior pole of the submandibular salivary gland. The anterior border just overlaps the posterior border of the masseter muscle and the posterior border overlaps the anterior border of the sternocleidomastoid muscle.

The superficial surface of the gland is covered by skin and platysma muscle. Some terminal branches of the great auricular nerve also lie superficial to the gland. At the superior border of the parotid lie the superficial temporal vessels with the artery in front of the vein. The auriculotemporal branch of the mandibular nerve runs at a deeper level just behind the superficial temporal vessels.

The branches of the facial nerve emerge from the anterior border of the gland. The parotid duct also emerges to run horizontally across the masseter muscle before piercing the buccinator muscle anteriorly to end at the parotid papilla. The transverse facial artery (a branch of the superficial temporal artery) runs across the area parallel to and approximately 1 cm above the parotid duct. The anterior and posterior branches of the facial vein emerge from the inferior border.

The deep (medial) surface of the parotid gland lies on those structures forming the parotid bed. Anteriorly, the gland lies over the masseter muscle and the posterior border of the mandibular ramus from the angle up to the condyle. As the gland wraps itself around the ramus it is related to the medial pterygoid muscle at its insertion on to the deep aspect of the angle. More posteriorly, the parotid is molded around the stylohyoid muscles and the styloglossus, stylohyoid, and stylopharyngeal muscles from below upwards. Behind this, the parotid lies on the posterior belly of the digastric muscle and the sternocleidomastoid muscle.

The digastric and the styloid muscles separate the gland from the underlying internal jugular vein, the external and internal carotid arteries and the glossopharyngeal, vagus, accessory, and hypoglossal nerves, and the sympathetic trunk.

The fascia that covers the muscles in the parotid bed thickens to form two named ligaments (Figure 1.3). The stylomandibular ligament passes from the stylloid process to the angle of the mandible. The mandibulostylohyoid ligament (the angular tract) passes between the angle of the mandible and the stylohyoid ligament. Inferiorly, it usually extends down to the hyoid bone. These ligaments are all that separates the parotid gland anteriorly from the posterior pole of the superficial lobe of the submandibular gland.

**CONTENTS OF THE PAROTID GLAND**

**The Facial Nerve**

From superficial to deep, the facial nerve, the auriculotemporal nerve, the retromandibular vein, and the external carotid artery pass through the substance of the parotid gland.

The facial nerve exits the skull base at the stylomastoid foramen. The surgical landmarks are important (Figure 1.4). To expose the trunk of the facial nerve at the stylomastoid foramen the dissection passes down the avascular plane between the parotid gland and the external acoustic canal until the junction of the cartilaginous and bony canals can be palpated. A small triangular extension of the cartilage points towards the facial nerve as it exits the foramen (Langdon 1998b). The nerve lies about
Surgical Anatomy, Embryology, and Physiology of the Salivary Glands

9 mm from the posterior belly of the digastric muscle and 11 mm from the bony external meatus (Holt 1996). The facial nerve then passes downwards and forwards over the styloid process and associated muscles for about 1.3 cm before entering the substance of the parotid gland (Hawthorn and Flatau 1990). The first part of the facial nerve gives off the posterior auricular nerve supplying the auricular muscles and also branches to the posterior belly of the digastric and stylohyoid muscles.

On entering the parotid gland the facial nerve divides into two divisions, temporofacial and cervicofacial, the former being the larger. The division of the facial nerve is sometimes called the pes anserinus due to its resemblance to the foot of a goose. From the temporofacial and cervicofacial divisions, the facial nerve gives rise to five named branches – temporal, zygomatic, buccal, mandibular, and cervical (Figure 1.5). The peripheral branches of the facial nerve form anastomotic arcades between adjacent branches to form the parotid plexus. These anastomoses are important during facial nerve dissection as accidental damage to a small branch often fails to result in any facial weakness due to dual innervation from adjacent branches. Davis et al. (1956) studied these patterns following the dissection of 350 facial nerves in cadavers. The anastomotic relationships between adjacent branches fell into six patterns (Figure 1.6). They showed that in only 6% of cases (type VI) is there any anastomosis between the mandibular branch and adjacent branches. This explains why, when transient facial weakness follows facial nerve dissection, it is usually the mandibular branch that is affected.

**Auriculotemporal Nerve**

The auriculotemporal nerve arises from the posterior division of the mandibular division of the trigeminal nerve in the infratemporal fossa. It runs backwards beneath the lateral pterygoid muscle between the medial aspect of the condylar neck and the sphenomandibular ligament. It enters the anteromedial surface of the parotid gland passing upwards and outwards to emerge at the superior border of the gland between the temporomandibular joint and the external acoustic meatus. This nerve communicates widely with the temporofacial division of the facial nerve and limits the mobility of the facial nerve during surgery (Flatau and Mills 1995). Further communications with the temporal and zygomatic branches loop around the
transverse facial and superficial temporal vessels (Bernstein and Nelson 1984).

Retromandibular Vein
The vein is formed within the parotid gland by the union of the superficial temporal vein and the maxillary vein. The retromandibular vein passes downwards and close to the lower pole of the parotid where it often divides into two branches passing out of the gland. The posterior branch passes backwards to unite with the posterior auricular vein on the surface of the sternocleidomastoid muscle to form the external jugular vein. The anterior branch passes forward to join the facial vein.

The retromandibular vein is an important landmark during parotid gland surgery. The division of the facial nerve into its temporofacial and cervicofacial divisions occurs just behind the retromandibular vein (Figure 1.7). The two divisions lie just superficial to the vein in contact with it. It is all too easy to tear the vein whilst exposing the division of the facial nerve!

External Carotid Artery
The external carotid artery runs deeply within the parotid gland. It appears from behind the posterior belly of the digastric muscle and grooves the parotid before entering it. It gives off the posterior auricular artery before ascending and dividing into its terminal branches, the superficial temporal and maxillary arteries at the level of the condyle. The superficial temporal artery continues vertically to emerge at the superior border of the gland and crosses the zygomatic arch. Within the substance of the parotid it gives off the transverse facial artery, which emerges at the anterior border of the gland to run across the face above the parotid duct. The maxillary artery emerges from the deep aspect of the gland anteriorly to enter the infratemporal fossa. The maxillary artery gives off the deep auricular artery and the anterior tympanic artery within the substance of the parotid. All these branches from the external carotid also give off numerous small branches within the parotid to supply the gland itself.

Parotid Lymph Nodes
Lymph nodes are found within the subcutaneous tissues overlying the parotid to form the preauricular nodes and also within the substance of the gland. There are typically 10 nodes within the substance of the gland, the majority being within the superficial lobe and therefore superficial to the plane of the facial nerve. Only one or two nodes lie within the deep lobe (Marks 1984; McKean, et al. 1985; Garatea-Crelgo, et al. 1993). All the parotid nodes drain into the upper deep cervical chain.
Parotid Duct

The parotid duct emerges from the anterior border of the parotid gland and passes horizontally across the masseter muscle. The surface markings of the duct are obtained by drawing a line from the lowest point of the alar cartilage to the angle of the mouth (Figure 1.8). This line is bisected and its midpoint is joined with a straight line to the most anterior point of the tragus. This line is divided into three equal parts and the middle section corresponds to the position of the parotid duct. The duct lies approximately 1 cm below the transverse facial vessels. The accessory lobe of the parotid gland, when present, drains into its upper border via one or two tributaries. Anastomosing branches between the buccal and zygomatic branches of the facial nerve cross the duct. At the anterior border of the masseter, the duct bends sharply to perforate the buccal pad of fat.

and the buccinator muscle at the level of the upper molar teeth. The duct then bends again to pass forward for a short distance before entering the oral cavity at the parotid papilla.

**Nerve Supply to the Parotid**

The parasympathetic secretomotor nerve supply comes from the inferior salivatory nucleus in the brain stem (Figure 1.9). From there, the fibers run in the tympanic branch of the glossopharyngeal nerve contributing to the tympanic plexus in the middle ear. The lesser petrosal nerve arises from the tympanic plexus leaving the middle ear and running in a groove on the petrous temporal bone in the middle cranial fossa. From here it exits through the foramen ovale to the otic ganglion, which lies on the medial aspect of the mandibular branch of the trigeminal nerve. Postsynaptic postganglionic fibers leave the ganglion to join the auriculotemporal nerve, which distributes the parasympathetic secretomotor fibers throughout the parotid gland. Some authorities suggest that there are also some parasympathetic innervations to the parotid from the chorda tympani branch of the facial nerve.

The sympathetic nerve supply to the parotid arises from the superior cervical sympathetic ganglion. The sympathetic fibers reach the gland via the plexus around the middle meningeal artery. They then pass through the otic ganglion without synapsing and innervate the gland through the auriculotemporal nerve. There is also sympathetic innervation to the gland arising from the plexuses that accompany the blood vessels supplying the gland.

Sensory fibers arising from the connective tissue within the parotid gland merge into the auriculotemporal nerve and pass proximally through the otic ganglion without synapsing. From there the fibers join the mandibular division of the trigeminal nerve. The sensory innervation of the parotid capsule is via the great auricular nerve.

**The Submandibular Gland**

**EMBRYOLOGY**

The submandibular gland begins to form at the 13 mm stage as an epithelial outgrowth into the mesenchyme forming the floor of the mouth in the linguogingival groove. This proliferates rapidly giving off numerous branching processes, which eventually develop lumina. Initially the developing gland opens into the floor of the mouth posteriorly, lateral to the tongue. The walls of the groove into which it drains come together to form the submandibular duct. This process commences posteriorly and moves forwards so that ultimately the orifice of the duct comes to lie anteriorly below the tip of the tongue close to the midline.

**ANATOMY**

The submandibular gland consists of a larger superficial lobe lying within the digastric triangle in the neck and a smaller deep lobe lying within the floor of the mouth posteriorly (Figure 1.10). The two lobes are continuous with each other around the posterior border of the mylohyoid muscle. As in the parotid gland, the two “lobes” are
not true lobes embryologically, as the gland arises as a single epithelial outgrowth (Langdon 1998a). However, surgically it consists of the two lobes as described previously. It is a mixed seromucinous gland.

The Superficial Lobe
The superficial lobe lies within the digastric triangle. Its anterior pole reaches the anterior belly of the digastic muscle and the posterior pole reaches the stylomandibular ligament. This structure is all that separates the superficial lobe of the submandibular gland from the parotid gland. It is important to realize just how close the lower pole of the parotid is to the posterior pole of the submandibular gland as confusion can arise if a mass in the region is incorrectly ascribed to the wrong anatomical structure (Figure 1.2). Superiorly, the superficial lobe lies medial to the body of the mandible. Inferiorly, it often overlaps the intermediate tendon of the digastic muscles and the insertion of the stylohyoid muscle. The lobe is partially enclosed between the two layers of the deep cervical fascia that arise from the greater cornu of the hyoid bone and is in intimate proximity of the facial vein and artery (Figure 1.11). The superficial layer of the fascia is attached to
Figure 1.10. The relationship of the superficial and deep lobes of the submandibular gland. (a) cross-sectional anatomy. (b) The superficial lobe from outside. (c) The relationship of the deep and superficial lobes to the mylohyoid muscle.
Figure 1.11. Superficial dissection of the left submandibular gland. The investing layer of the deep cervical fascia is elevated off of the submandibular gland and the facial vein is identified.

The lower border of the mandible and covers the inferior surface of the superficial lobe. The deep layer of fascia is attached to the mylohyoid line on the inner aspect of the mandible and therefore covers the medial surface of the lobe.

The inferior surface, which is covered by skin, subcutaneous fat, platysma, and the deep fascia, is crossed by the facial vein and the cervical branch of the facial nerve, which loops down from the angle of the mandible and subsequently innervates the lower lip. The submandibular lymph nodes lie between the salivary gland and the mandible. Sometimes one or more lymph nodes may be embedded within the salivary gland.

The lateral surface of the superficial lobe is related to the submandibular fossa, a concavity on the medial surface of the mandible, and the attachment of the medial pterygoid muscle. The facial artery grooves its posterior part lying at first deep to the lobe and then emerging between its lateral surface and the mandibular attachment of the medial pterygoid muscle from which it reaches the lower border of the mandible.

The medial surface is related anteriorly to the mylohyoid from which it is separated by the mylohyoid nerve and submental vessels. Posteriorly, it is related to styloglossus muscle, the stylohyoid ligament, and the glossopharyngeal nerve separating it from the pharynx. Between these, the medial aspect of the lobe is related to hyoglossus muscle from which it is separated by styloglossus muscle, the lingual nerve, submandibular ganglion, hypoglossal nerve, and deep lingual vein. More inferiorly, the medial surface is related to the stylohyoid muscle and the posterior belly of digastric.

The Deep Lobe

The deep lobe of the gland arises from the superficial lobe at the posterior free edge of the mylohyoid muscle and extends forward to the back of the sublingual gland (Figure 1.12). It lies between mylohyoid inferolaterally, hyoglossus, and styloglossus muscles medially, the lingual nerve superiorly, and the hypoglossal nerve and deep lingual vein inferiorly.

The Submandibular Duct

The submandibular duct is about 5 cm long in the adult. The wall of the submandibular duct is thinner than that of the parotid duct. It arises from numerous tributaries in the superficial lobe and emerges from the medial surface of this lobe just behind the posterior border of the mylohyoid. It crosses the deep lobe, passing upwards and slightly backwards for 5 mm before running forwards between the mylohyoid and hyoglossus...
muscles. As it passes forward, it runs between the sublingual gland and genioglossus to open into the floor of the mouth on the summit of the sublingual papilla at the side of the lingual frenum just below the tip of the tongue. It lies between the lingual and hypoglossal nerves on the hyoglossus. At the anterior border of hyoglossus muscle it is crossed by the lingual nerve. As the duct traverses the deep lobe of the gland it receives tributaries draining that lobe.

**Blood Supply and Lymphatic Drainage**
The arterial blood supply arises from multiple branches of the facial and lingual arteries. Venous blood drains predominantly into the deep lingual vein. The lymphatics drain into the deep cervical group of nodes, mostly into the jugulo-omohyoid node, via the submandibular nodes.

**Nerve Supply to the Submandibular Gland**

**Parasympathetic Innervation**
The secretomotor supply to the submandibular gland arises from the submandibular (sublingual) ganglion. This is a small ganglion lying on the upper part of the hyoglossus muscle. There are additional ganglion cells at the hilum of the gland. The submandibular ganglion is suspended from the lingual nerve by anterior and posterior filaments (Figure 1.13).

The parasympathetic secretomotor fibers originate in the superior salivatory nucleus and the preganglionic fibers then travel via the facial nerve, chorda tympani, and lingual nerve to the ganglion via the posterior filaments connecting the ganglion to the lingual nerve. They synapse within the ganglion and the postganglionic fibers innervate the submandibular and sublingual glands (Figure 1.9). Some fibers are thought to reach the lower pole of the parotid gland.

**Sympathetic Innervation**
The sympathetic root is derived from the plexus on the facial artery. The postganglionic fibers arise from the superior cervical ganglion and pass through the submandibular ganglion without synapsing. They are vasomotor to the vessels supplying the submandibular and sublingual glands. Five or six branches from the ganglion supply the submandibular gland and its duct. Others pass back into the lingual nerve via the anterior filament to innervate the sublingual and other minor salivary glands in the region.

**Sensory Innervation**
Sensory fibers arising from the submandibular and sublingual glands pass through the ganglion without synapsing and join the lingual nerve, itself a branch of the trigeminal nerve.

**The Sublingual Gland**

**EMBRYOLOGY**
The sublingual gland arises in 20 mm embryos as a number of small epithelial thickenings in the linguogingival groove and on the outer side of the groove. Each thickening forms its own canal and so many of the sublingual ducts open directly onto the summit of the sublingual fold. Those that arise within the linguogingival groove end up draining into the submandibular duct.

**ANATOMY**
The sublingual gland is the smallest of the major salivary glands. It is almond shaped and weighs approximately 4 g. It is predominantly a mucous gland. The gland lies on the mylohyoid and is
covered by the mucosa of the floor of the mouth, which is raised as it overlies the gland to form the sublingual fold. Posteriorly, the sublingual gland is in contact with the deep lobe of the submandibular gland. The sublingual fossa of the mandible is located laterally and the genioglossus muscle is located medially. The lingual nerve and the submandibular duct lie medial to the sublingual gland between it and the genioglossus.

**Sublingual Ducts**
The gland has a variable number of excretory ducts ranging from 8 to 20. The majority drain into the floor of the mouth at the crest of the sublingual fold. A few drain into the submandibular duct. Sometimes, a collection of draining ducts coalesce anteriorly to form a major duct (Bartholin's duct) which opens with the orifice of the submandibular duct at the sublingual papilla.

**Blood Supply, Innervation, and Lymphatic Drainage**
The arterial supply is from the sublingual branch of the lingual artery and also the submental branch of the facial artery. Innervation is via the sublingual ganglion as described above. The lymphatics drain to the submental nodes.

**Minor Salivary Glands**
Minor salivary glands are distributed widely in the oral cavity and oropharynx. They are grouped as labial, buccal, palatoglossal, palatal, and lingual glands. The labial and buccal glands contain both mucous and serous acini, whereas the palatoglossal glands are mucous secreting. The palatal glands that are also mucous secreting occur in both the hard and soft palates. The anterior and posterior lingual glands are mainly mucous. The anterior glands are embedded within the muscle ventrally and they drain via four or five ducts near the lingual frenum. The posterior lingual glands are located at the root of the tongue. The deep posterior lingual glands are predominantly serous. Additional serous glands (of von Ebner) occur around the circumvallate papillae on the dorsum of the tongue. Their watery secretion is thought to be important in spreading taste stimuli over the taste buds.

**Histology of the Salivary Glands**
The salivary glands are composed of large numbers of secretory acini, which may be tubular or globular in shape. Each acinus drains into a duct. These microscopic ducts coalesce to form lobular ducts. Each lobule has its own duct and these then merge to form the main ducts. The individual lobes and lobules are separated by dense connective tissue which is continuous with the gland capsule. The ducts, blood vessels, lymphatics, and nerves run through and are supported by this connective tissue.

The acini are the primary secretory organs but the saliva is modified as it passes through the intercalated, striated, and excretory ducts before being discharged into the mouth and oropharynx (Figure 1.14). The lobules also contain significant amounts of adipose tissue particularly in the parotid gland. The proportion of adipose tissue relative to excretory acinar cells increases with age.

In the human parotid, the excretory acini are almost entirely serous. In the submandibular gland, again, the secretory units are mostly serous but there are additional mucous tubules and acini. In some areas the mucinous acini have crescentic “caps” of serous cells called serous demilunes. In the sublingual gland the acini are almost entirely mucinous, although there are occasional serous acini or demilunes.

The serous cells contain numerous proteinaeous secretory (zymogen) granules. These granules contain high levels of amylase. In addition, the secretory cells produce kallikrein, lactoferrin, and lysozyme. In mucous cells, the cytoplasm is packed with large pale secretory droplets.

Initially the secretory acini drain into intercalated ducts. These function mainly to conduct the saliva but they may also modify the electrolyte content and secrete immunoglobulin A. The intercalated ducts drain into striated ducts, which coalesce into intralobular and extralobular collecting ducts. The intercalated duct cells are very active metabolically and they transport potassium and bicarbonate into saliva. They reabsorb sodium and chloride ions so that the resulting saliva is hypotonic. They also secrete immunoglobulin A, lysozyme, and kallikrein. The immunoglobulin is produced by plasma cells adjacent to the striated duct cells and it is then transported through the epithelial lining into the saliva. The main collecting
ducts are simple conduits for saliva and do not modify the composition of the saliva.

Myoepithelial cells are contractile cells closely related to the secretory acini and also much of the duct system. The myoepithelial cells lie between the basal lamina and the epithelial cells. Numerous cytoplasmic processes arise from them and surround the serous acini as basket cells. Those associated with the duct cells are more fusiform and are aligned along the length of the ducts. The cytoplasm of the myoepithelial cells contains actin myofilaments which contract as a result of both parasympathetic and sympathetic activity. Thus, the myoepithelial cells “squeeze” the saliva out
of the secretory acini and ducts and add to the salivary secretory pressure.

**Control of Salivation**

There is a continuous low background saliva production, which is stimulated by drying of the oral and pharyngeal mucosa. A rapid increase in the resting levels occurs as a reflex in response to masticatory stimuli including the mechanoreceptors and taste fibers. Other sensory modalities such as smell are also involved. The afferent input is via the salivatory centers, which are themselves influenced by the higher centers. The higher centers may be facilitory or inhibitory, depending on the circumstances. The efferent secretory drive to the salivary glands passes via the parasympathetic and sympathetic pathways. There are no peripheral inhibitory mechanisms.

Cholinergic nerves (parasympathetic) often accompany ducts and branch freely around the secretory endpieces (acini). Adrenergic nerves (sympathetic) usually enter the glands along the arteries and arterioles and ramify with them. Within the glands, the nerve fibers intermingle such that cholinergic and adrenergic axons frequently lie in adjacent invaginations of a single Schwann cell. Secretion and vasoconstriction are mediated by separate sympathetic axons whereas a single parasympathetic axon may, through serial terminals, result in vasodilatation, secretion, and constriction of myoepithelial cells.

Secretory endpieces are the most densely innervated structures in the salivary glands. Individual acinar cells may have both cholinergic and adrenergic nerve endings. The secretion of water and electrolytes, which accounts for the volume of saliva produced, results from a complex set of stimuli which are largely parasympathetic. The active secretion of proteins into the saliva depends upon the relative levels of both sympathetic and parasympathetic stimulation.

Although the ducts are less densely innervated than secretory acini, they do influence the composition of the saliva. Adrenal aldosterone promotes resorption of sodium and secretion of potassium into the saliva by striated ductal cells. Myoepithelial cell contraction is stimulated predominantly by adrenergic fibers, although there may be an additional role for cholinergic axons.

**Summary**

- Although embryologically the parotid consists of a single lobe, anatomically the facial nerve lies in a distinct plane between the anatomical superficial and deep lobes.
- There are fixed anatomical landmarks indicating the origin of the extracranial facial nerve as it leaves the stylomastoid foramen.
- The lower pole of the parotid gland is separated from the posterior pole of the submandibular gland by only thin fascia. This can lead to diagnostic confusion in determining the origin of a swelling in this area.
- The relationship of the submandibular salivary duct to the lingual nerve is critical to the safe removal of stones within the duct.
- Great care must be taken to identify the lingual nerve when excising the submandibular gland. The lingual nerve is attached to the gland by the parasympathetic fibers synapsing in the submandibular (sublingual) ganglion.
- The sublingual gland may drain into the submandibular duct or it may drain directly into the floor of the mouth via multiple secretory ducts.

**References**


Chapter 1


Chapter 2
Diagnostic Imaging of Salivary Gland Pathology

Pradeep K. Jacob, MD, MBA and J. Michael McCoy, DDS

1Department of Radiology, University of Tennessee at Chattanooga, College of Medicine, Chattanooga, TN, USA
2Departments of Oral and Maxillofacial Surgery, Pathology, and Radiology, University of Tennessee Medical Center, Knoxville, TN, USA

Outline

Introduction
Imaging Modalities
Computed Tomography (CT)
  CT Technique
  Advanced Computed Tomography
Magnetic Resonance Imaging (MRI)
  MRI Technique
  Spin Echo T1
  Spin Echo T2
  Proton Density Images (PD)
  Gradient Recalled Echo Imaging (GRE)
  Short Tau Inversion Recovery (STIR)
  Gadolinium (Gd) Contrast
  Fluid Attenuation Inversion Recovery (FLAIR)
  Diffusion Weighted Images (DWI)
  MR Spectroscopy (MRS)
  Dynamic Contrast Enhanced Magnetic Resonance Imaging
  Other Magnetic Resonance Imaging Techniques
Ultrasonography (US)
  Ultrasound Technique
  Sialography
  Radionuclide Imaging (RNI)
  Positron Emission Tomography (PET)
  Positron Emission Tomography/Computed Tomography (PET/CT)
Diagnostic Imaging Anatomy
  Parotid Glands
  Submandibular Glands
  Sublingual Glands
  Minor Salivary Glands
  Pathology of the Salivary Glands
    Vascular Lesions
      Lymphangioma (Cystic Hygroma)
      Hemangioma
    Acute Sialadenitis
    Chronic Sialadenitis
    HIV–Lymphoepithelial Lesions
    Mucous Escape Phenomena
    Sialadenosis (sialosis)
    Sialolithiasis
    Sjogren Syndrome
    Sarcoidosis
    Congenital Anomalies of the Salivary Glands
    First Branchial Cleft Cyst
    Neoplasms – Salivary, Epithelial
      Benign
        Pleomorphic Adenoma
        Warthin Tumor
        Oncocytoma
        Malignant
        Mucoepidermoid Carcinoma
        Adenoid Cystic Carcinoma
    Neoplasms – Non-Salivary
      Benign
        Lipoma
        Neurogenic Tumors
        Malignant
        Lymphoma
        Metastases
Summary
References
Introduction

Anatomic and functional diagnostic imaging plays a central role in modern medicine. Virtually all specialties of medicine to varying degrees depend on diagnostic imaging for diagnosis, therapy, and follow-up of treatment. Because of the complexity of the anatomy, treatment of diseases of the head and neck, including those of the salivary glands, are particularly dependent on quality medical imaging and interpretation. Medical diagnostic imaging is divided primarily into two major categories, anatomic and functional. The anatomic imaging modalities include computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography (US). Although occasionally obtained, plain film radiography for the head and neck, including salivary gland disease, is mostly of historical interest. In a similar manner, the use of sialography has been significantly reduced, although both plain films and sialography are of some use in imaging sialoliths. Functional diagnostic imaging techniques include planar scintigraphy, single photon emission computed tomography (SPECT), positron emission tomography (PET), and magnetic resonance spectroscopy (MRS), all of which are promising technologies. Recently, the use of a combined anatomic and functional modality in the form of PET/CT has proved invaluable in head and neck imaging. Previously widely employed procedures including gallium radionuclide imaging are less important today than in the past.

Imaging Modalities

COMPUTED TOMOGRAPHY (CT)

CT has become indispensable in the diagnosis, treatment and follow-up of diseases of the head and neck. The latest generation of multiple-row detector CT (MDCT) provides excellent soft-tissue and osseous delineation. The rapid speed with which images can be obtained along with the high spatial resolution and tissue contrast makes CT the imaging modality of choice in head and neck imaging. True volumetric data sets obtained from multidetector row scanners allow for excellent coronal, sagittal or oblique reformation of images as well as a variety of 3-D renderings. This allows the radiologist and surgeon to characterize a lesion, assess involvement of adjacent structures or local spread from the orthogonal projections or 3-D rendering. The ability to manipulate images is critical when assessing pathology in complex anatomy, such as evaluation of parotid gland masses to determine deep lobe involvement, facial nerve involvement, or extension into the skull base. Images in the coronal plane are important in evaluating the submandibular gland in relation to the floor of mouth. Lymphadenopathy and its relationship to the carotid sheath and its contents and other structures are also well delineated. CT is also superior to MRI in demonstrating bone detail and calcifications. CT is also the fastest method of imaging head and neck anatomy. Other advantages include widespread availability of scanners, high resolution images, and speed of image acquisition also reduces motion artifacts. Exposure to ionizing radiation and the administration of IV contrast are the only significant disadvantages to CT scanning.

CT Technique

The CT scanner contains a gantry, which holds an X-ray tube and a set of detectors. The X-ray tube is positioned opposite the detectors and is physically coupled. A “fan beam” of X-rays is produced and passes through the patient to the detectors as the tube and detector rotate around the patient. In newer generation of scanners, the multiple rows of detectors are fixed around the gantry and only the tube rotates. A table carries the patient through the gantry. The detectors send signals, dependent on the degree of X-ray attenuation, to a computer that uses this data to construct an image using complex algorithms.

For most CT studies (especially in the head and neck) intravenous contrast is administered. IV contrast is a solution consisting of organic compounds bonded with Iodine molecules. Iodine is a dense atom with an atomic weight of 127, which is good at absorbing X-rays and is biocompatible. IV contrast readily attenuates the X-ray beam at concentrations optimal for vascular and soft tissue “enhancement,” but short of causing attenuation related artifacts. Streak artifacts, however, can occur if the concentration is too high, as seen occasionally at the thoracic inlet and supraclavicular region from dense opacification of the subclavian vein during rapid bolus injection of IV contrast.

CT of the neck should be performed with intravenous contrast whenever possible to optimize delineation of masses, inflammatory or
infectious changes in the tissues, and enhance vascular structures. Imaging is obtained from the level of the orbits through the aortic arch in the axial plane with breath hold. The images are reconstructed using a computer algorithm to optimize soft tissue delineation, and displayed in soft tissue window and level settings (Figures 2.1 and 2.2). In a similar manner images are reconstructed using a computer algorithm to optimize bone details as more sharp and defined (Figure 2.3). The lung apex is often imaged in a complete neck evaluation and displayed using lung window settings (Figure 2.4a). Dedicated CT scans of the chest are beneficial in the postoperative evaluation of patients with salivary gland malignancies as lung nodules can be observed, possibly indicative of metastatic disease (Figure 2.4b). Multiplanar reformatted images of the neck are obtained typically in the coronal and sagittal planes, (Figures 2.5 and 2.6), although they may be obtained in virtually any plane desired or in a 3-D rendering.

The Hounsfield unit (H) (named after Godfrey Hounsfield, inventor of the CT scanner) is the unit of density measurement for CT. These units are assigned based on the degree of attenuation of
the X-ray beam by tissue in a given voxel (volume element) and are assigned relative to water (0 H) (Table 2.1). The scale ranges from −1024 H for air, to +4000 H for very dense bone. The images are created based on a grayscale from black (−1024 H) to white (+4000 H) and shades of gray. Despite

Figure 2.4. Axial CT of the neck at the thoracic inlet in lung windows demonstrating lung parenchyma (a). Axial image of dedicated CT of chest demonstrating cannon ball lesions in a patient previously treated for adenoid cystic carcinoma of the palate (b). These lesions are representative of diffuse metastatic disease of the lungs, but not pathognomonic of adenoid cystic carcinoma.

Figure 2.5. Coronal CT reformation of the neck in soft tissue window at the level of the submandibular glands. Orthogonal images with MDCT offer very good soft tissue detail in virtually any plane of interest in order to assess anatomic and pathologic relationships.

Figure 2.6. Sagittal CT reformation of the neck in soft tissue window at the level of the parotid gland. Note the accessory parotid gland (black arrow) sitting atop the parotid (Stensen) duct (thin white arrow). Also note the retromandibular vein (large white arrow) and external auditory canal.